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## TECHNICAL REPORT Nr 129

## DEVELOPMENT OF THE AUXILIARY APPARATUS OF THE RECTIFIER UNIT St. 7/6

## Contents:

type St 7/6 6-anode -

Description of the auxiliary apparatus developed for the rectifier units  
 (QOG 7/6 tank) including equipment for control, ignition and excitation, anode and grid blocking, cooling and indication, which corresponds with the vessels for rectifier units.

Two types of rectifier units were developed, with and without grid control. A short-circuit cutoff by means of grid blocking is provided for in both cases. At the end, some data are given which might be useful in the operation of such units.

## Summary:

Two standard versions have been chosen for the auxiliary apparatus of the QOG 7/6 vessels. All units are equipped with ignition and excitation devices, ventilation control, anode heating, indication devices and grid blocking of the same design. The version with grid control is designed for the supply of electric motors, electrochemical equipment and similar apparatus, while the second version without control is designed for use especially by railroads.

Development proceeded step by step. In the first unit some features were taken over unchanged from the AEG design, but changes and improvements were gradually introduced on the basis of the experiences gained.

The standard unit, in its final design, is built as follows:

The three-phase excitation is supplied by three single-phase <sup>L<sub>1</sub>, L<sub>2</sub>, L<sub>3</sub></sup> transformers.

The ignition rod is supplied with DC through dry elements. After ignition has taken place, it is shut off, while the ignition coil continues to receive current, so that the ignition rod will not be immersed in the mercury. The speed of the ventilator is regulated in two stages, depending on the temperature of the vessel.

A signal lamp indicates failure of the excitation, excessive temperature of the vessel, and response of the grid blocking.

At the no-load stage, and under low load, the anodes are heated by filaments.

The grid control is accomplished by means of voltage pulses, generated by

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oversaturated transformers made of standard transformer sheet-iron. The voltage supplied to the control unit is carefully filtered, so that the control will not be affected even if bad distortions of the line voltage should occur. The adjustment of the ignition valves should in general be performed by means of rotary regulators, but it can also be accomplished by pre-magnetisation of the grid transformers with DC. This also affords the possibility of compound regulation in case of difficulties.

In uncontrolled units, the control grids of the vessels (which are always built in) are impressed with a constant sinusoidal voltage.

The short-circuit ~~whether~~ cutoff by means of grid blocking is carried out with the aid of relays activated by primary converters.

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**SECRET****A. Introduction and Presentation of Problem**

The rectifier ~~vacuum~~ <sup>tank</sup> QOG 7/6, developed by the Rectifier Bureau, has the following output data:

300 v, 1500 a.

1000 v, 600 a.  
<sup>unit</sup>

It is a ~~vacuum~~ which can satisfy the requirements of industry, supply current for electric railroads, and be used by a number of other types of consumers. It is thus to be expected that its production will reach high figures. The auxiliary apparatus required for the operation of the rectifier has also been developed in a manner which allows large-scale production. It was necessary for that purpose to design as few versions as possible for the auxiliary apparatus. After several possibilities had been evaluated, it was found that the requirements of practical use could be satisfied by two basic designs, one with grid control and grid blocking, and the other without grid control, but also with grid blocking.

All other auxiliary apparatus, i.e. ignition, excitation, cooling, and indication could be built practically alike for both versions.

It is practical to combine the ~~vacuum~~ <sup>tank</sup> and this standard ~~rectifier~~ <sup>auxiliary equipment</sup> to one unit. In the course of the development, after the main points of design had been established, two rectifier units were built first (Nos. 96 and 97). For the sake of speedy completion, some parts were built of material which happened to be on hand at the Rectifier Bureau at the time. On the basis of the experience gained from testing of these prototypes, the following model was progressively improved.

This report describes the auxiliary apparatus and their circuits, while the structure of the rectifier unit, including its auxiliary apparatus, is given in report HG 125. HG 125 also contains a compilation, by type and number of items built, of the rectifier units constructed by the Rectifier Bureau until now.

The ~~vacuum~~ <sup>tank</sup> QOG 7/6 ~~used~~ <sup>for</sup> these rectifier <sup>units</sup> have been discussed previously in a number of reports:

Hg 101: Vacuum technique of pumpless rectifiers

Hg 103: Design and dimensioning of the pumpless rectifier

Hg 104: The discharge properties of the pumpless rectifier

Hg 61: Experiments with Q OG 7/6 rectifiers during 1947

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~~SECRET~~Fig 68 : Development of the rectifier ~~Q00~~ 7/6 During 1949Fig 69 : Further development of the Q00 7/6 rectifier during 1949,  
etc.For that reason, this report does not deal with the ~~vessels~~ in detail.~~tank~~2. Development of the Circuits and the Apparatus

## a) Ignition and Excitation

The AEG built the pumpless Q00 6/6 vessels with two exciter anodes. The first <sup>tanks</sup> ~~vessels~~ built by the Rectifier Bureau also had two exciter anodes. It turned out, however, that the readiness to ignite of the grids of the two anodes not in the immediate vicinity of the exciter anodes was unsatisfactory. The later vessels were therefore equipped with three exciter anodes. This innovation was effective, and the grids now ignited without any difficulty. All but one of the vessels equipped with two exciter anodes failed for various reasons. Only the last one was found to be ~~incompletely~~ acceptable, was equipped with the auxiliary apparatus and was shipped to the Soviet Union.

Thus the first rectifier unit No. 96 with the auxiliary apparatus unit No. 170 and <sup>tank</sup> vessel No. 45 was built, according to circuit diagram 201-S2-2212 and apparatus list No. 100.

A single-phase/exciter transformer which was on hand was used for the excitation, but the exciter circuit customary at AEG was not used. According to the experiences made with the HQNG 1/1 rectifiers, it has the ~~advantage~~ disadvantage that the ignition rod is not always lifted out of the mercury. This brings about the danger, that the cathode spot might become fixed on the ignition rod, which ~~might~~ generally causes damage to the rod at high loads. For that reason, the circuit later used for high-voltage rectifiers was chosen. In this circuit, the ignition rod and the ignition are connected to the DC generated by dry rectifiers. The circuit is shown in the appended diagram 201-S2-2212.

When the auxiliary apparatus is turned on, the secondary voltage of the exciter transformer ~~is~~ goes through the series chokes 6 and 14 and on the exciter anodes EA<sub>1</sub> and EA<sub>2</sub>, and on the dry rectifier 7. The rectified voltage is supplied to the ignition coil 8. The DC flows through the ignition coil, the variable resistance 44 and the rest contact of the exciter relay 4, to the ignition anode 2A, then through the cathode mercury, the coil of the exciter relay, the exciter

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smoothing choke 3, and the exciter anode 2, and then back to the exciter transformer. The ignition coil is lifted, and a spark is generated which ignites the exciter anodes. Thus the exciter current of about 10 a is generated thereby causing the exciter relay 4 to close. The ignition anode is shut off, and the ignition coil DC is directly switched to the exciter transformer. The current now flowing in the ignition coil is set at 1 a by means of the resistance 11, so that the ignition anode will not dip into the mercury even if the voltage in the line drops to 95% (it drops at 0.62 a). The exciter current can be checked at the ammeter 2. If there is no load on the vessel, it is 9 a. If the vessel is loaded, it rises to 11 to 12 a. If the exciter relay is closed, a resistance 5 lies in parallel with the relay coil in order to lower the load. This is necessary, because the relay IP 10 has a comparatively high closing current. If this expedient is not used, there is no guarantee that the exciter relay will close ~~well~~ properly when the line voltage has dropped. The exciter circuit is protected by a fuse 20. A "Silit" resistance <sup>770</sup> lies between cathode and tank to stabilize the potential of the tank. Exact data on the parts are contained in the appended parts list AL 100. [Note: Not included in the photostat 7 and in the construction specifications.]

All other vessels have three exciter anodes. A new exciter circuit had to be developed for this purpose. The circuit of three single-phase ~~single~~ transformers was chosen for this, because it offers the following advantages:

1. The choke coils in the lines of the exciter anodes can be omitted.
2. The smoothing choke in the exciter circuit also can be dispensed with.
3. The ~~single~~ transformers can be designed in such a manner that the primary and the secondary windings are placed on separate legs. Thus the two windings can easily be insulated very well, and no special isolating transformer between the exciter circuit and the general auxiliary circuit is required, even at high cathode voltages.

This circuit has been used for all subsequent rectifier units. Its features are shown in the circuit diagrams 201-82-2711, 2712, and 4299. The ~~stray~~ transformers are equipped with cores of an iron cross-section of 10,000 sq. cm. a mean ferromagnetic length of 500 cm, and an air gap of about 2 x 1 mm. The primary winding is of lacquered "ZW" copper wire of 1.6 mm diameter. The star point is

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located on taps, so that the greater part of the secondary winding is used for supplying of the excitation, and the smaller part for that supplying of the ignition anode and the ignition coil. The excitation and the ignition must be supplied from two separate parts of the winding, because the voltage in the secondary winding breaks down during the ignition period of the associated anode. The retaining voltage for the ignition rod would also break down, if it were obtained from taps of the exciter winding. In this arrangement, however, the voltage for the ignition coil is taken off at opposite phase of the exciter anode voltage, and is thus not affected by the exciter currents. The no-load voltage of the excitation was chosen at about 80 V<sub>eff</sub>, on the basis of experiments. It must be relatively high, because the ignition voltage of the exciter anodes of the ~~wound~~<sup>tent</sup> Q00 7/6 depends to a great extent on the load of the ~~wound~~<sup>tent</sup>, and beginning 250. Consequently, the exciter current will vary greatly between no-load and load conditions, if the exciter voltage is not sufficiently high. For the exact adjustment of the exciter current, the cathode line contains a 0.6 ohm resistance. The "Silit" rods 2~~mm~~<sup>mm</sup> are provided for the protection of the exciter winding in case of overvoltages during arrester or similar occurrences.

The ignition voltage is practically the same as described above, with the exception that the voltage for the ignition is obtained from a three-phase dry rectifier.

The first units contained an ignition coil of 750 turns of 1.2 mm diameter "CuL" wire. A current of 3.2 a constantly flows through this coil. The three <sup>-dry</sup> <sup>slack</sup> elements each consisted of five plates of 100 x 100 mm. The units Nos. 101, 102, and 103, which were the last ones built, had the number of turns increased to 1575, of "CuL" wire of 0.9 mm diameter. This allows the use of a lower ignition coil current, of only 1.3 a, so that the <sup>slack</sup> elements could be made correspondingly smaller, with plates of a dimension of 60 x 60 mm.

#### b) Control and grid <sup>Supply</sup> impedance:

A number of fields of application require rectifying units with ~~constant~~ voltage regulation. These are especially electric motors, electrochemical apparatus, inverters etc. In other cases, such as units for supplying of electric railroad, voltage control is not essential. Accordingly, some units were built with voltage control (Nos. 97 - 100, circuit diagrams 201-32- 3212, 4299), while others (Units Nos. 96, 101, 102, 103, circuit diagrams 201-~~32~~- 3211, 3213), were

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built without voltage control. Since all units are equipped with control grids, both for the sake of easier manufacture, as well as for the purpose of taking advantage of the possibility of grid blocking, even uncontrolled units must be supplied (?) provided with a device for the igniting of the grids. A sinusoidal voltage is chosen for this purpose (cf. circuit diagram 201-S2-271). The grids are supplied by a six-phase transformer 32 through grid resistances 41 of 2 kilohm, 25 w. The transformer has a secondary phase voltage of 240 v. Its primary connection is built in such a way that a maximum number of possibilities of matching is available, in order to match the phase position of the grids at any position of the auxiliary voltage line to the phase position of the engine. For the exact adjustment of the phase position, the grid transformer 32 is also equipped with additional windings of 120 v each. They can be added in zig-zag arrangement to the basic winding, as necessary. Resistances 44 are inserted in the line between the cathode and the ~~anode~~ star point of the grid transformer, in order to shorten the ignition period of the grids. Without these resistances, the grids would remain ignited for 180° el., while the resistances are dimensioned to reduce the ignition period of the grids to 120° el., thus matching it to the ignition period of the engine.

Condensers of 5000  $\mu$ farads are placed between grids and cathodes, to keep high-frequency overvoltages away from the grids. The controlled units (cf. circuit diagrams 201-S2-3212 and 201-S2-4206) are equipped with voltage peak control devices operating with oversaturated transformers made of standard transformer sheet-iron. This control device is described in detail by Dr. Jüdts in report Eg G 6, and in the memorandum AT 51 by Filberich. It has a transformer 35 which supplies the grid transformer 37 and the dry rectifiers for the negative grid bias voltage 40. The grid transformers are placed before filter devices consisting of chokes 38 and condensers 39, which guarantee proper operation of the control even if the supply voltage should be badly distorted. The condensers also compensate the high input of reactive load in the control device, so that the transformer 35 can be given comparatively small dimensions. Another set of chokes 36 causes the current flowing through the grid transformers to assume a curve of triangular shape. This allows displacement over a wide range of the control voltage pulses (Saturation) by means of the DC pre-magnetization of the grid transformers without changing the amplitude of the voltage peaks. For this purpose, the grid transformers are

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equipped with smooth windings which are run to terminals 7 and 8 through a smoothing choke 40. This arrangement is designed chiefly for purposes of compounding, while rotary regulators are provided for the normal displacement of the ignition valves for the voltage regulation. These rotary regulators are set up outside of the unit, at a central disk or a similar arrangement. The rectifiers built in 1949 and shipped to the Soviet Union were not equipped with rotary regulators because none are to be obtained at the present time.

#### a) Grid blocking:

In the first unit No. 96 (Circuit diagram 201-92-2212), the grid blocking in the case of short circuit was carried out by means of a polarized relay (40). The contacts on the primary side of the main transformer supply a relay 26 which supplies a voltage corresponding to the load of the rectifier transformer 26 which supplies a voltage corresponding to the load of the rectifier on its secondary side. This voltage is rectified and then applied to the operating coil of the relay. The resistances 42 serve for the adjustment of the response thru a current transformer (the base-a secondary of unit), and resistance 45 reduces the time current (the base-a secondary of unit), and resistance 45 reduces the time constant of the circuit. The individual magnitudes of the circuit are chosen in such a manner that the grid blocking relay will respond if (the ninth) amount of total current of the set is exceeded. The response time is 10 milliseconds, and 3 milliseconds at ten times the rated current. (Vabatshyplakan-had-right start over immediately.)

When the relay responds, the negative bias voltage of the dry rectifiers runs through the contacts 2 and 3, the dry elements 33 and the resistances 34 to the grids of the rectifier.

The restoring circuit operates as follows: When the rectifier unit is turned on, the grids are first blocked by the negative bias voltage generated by the dry rectifiers 30 through contacts 14 and 15 of the auxiliary relay. At the same time, however, the coil of the auxiliary relay 40 receives voltage through the rest contact of the push button 47 and the rest contact 9 and 10 of the relay 29. The relay closes and releases the grids. If blocking occurs now, contact 9 and 10 of the relay 29 opens and relay 40 opens, so that the negative bias will also reach the grids through its contact 14 and 15. If this blocking is now to be eliminated, push-button 47 is operated. The restoring coil of 7 and 8 of the 29 blocking relay is excited through its operating contact, so that it opens its contact 2 and 3. The rectifier will remain blocked, until the push button is

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released. Then the auxiliary relay with 40-411 closes again, and -411 breaks the connection to the grids with its rest contact 14 and 15. This circuit protects the operating contact of the blocking relay 59, because it does not have to draw any current.

In the later units, polarised relays were no longer used, because they were not available. A circuit was therefore developed from simple relays, which operates along similar lines. Its mode of operation is as follows (cf. circuit diagram 211-52-3211):

When the rectifier unit is turned on, the rectifier is blocked through the rest contacts 16 and 18 of the auxiliary relay 56. The coil of the relay 56 receives voltage through the rest contacts of the restoring relay 57 and 1 and 2 of the blocking relay 54. The relay 56 closes and unblocks the grids. In case of short circuit, the blocking relay 54 closes and the negative bias voltage reaches the grids through the operating contacts 7 and 8, and 10 and 11, which are in series. At the same time, the coil receives voltage through its contact 1 and 2, so that it remains closed, while relay 56 opens because contact 1 and 2 opens and thus closes a parallel line for the negative bias voltage. Unblocking is accomplished by pressing the pushbutton 59. The restoring relay 57 then closes and the blocking relay 54 opens. When the pushbutton is released, the auxiliary relay 56 closes again and interrupts the blocking current, so that the contacts of the blocking relay will be protected also in this circuiting arrangement. The response times of these relays are approximately the same as those of the polarized relays.

#### a) Cooling

The rectifier is cooled by a centrifugal blower, supplying 1.2 cu.m air at a static pressure of 60 mm water at approximately 1400 rpm. It is driven by an induction asynchronous three-phase motor with a squirrel-cage rotor. The motor has an output of 2.5 kw. In an attempt to have the vessel always operate under the most favorable temperature conditions, to reduce the consumption of energy by the blower, and to keep the noise to a minimum, AEG had already developed a two-stage rpm governor which operated in dependence on the temperature of the vessel. For that purpose, the bottom of the vessel contains three pockets which hold

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*lie*  
 bimetal temperature contacts (so-called "Birka" regulators) whose contacts close at different temperatures.

The rpm control of an ~~asynchronous~~ motor is a difficult problem. The best practical solution is undoubtedly the use of a motor with ~~resonable~~ poles. Such motors are not being made in the Soviet Zone, however, and the method of ATO, which employs series chokes, was retained (cf. circuit diagram 201-92-2711). The first temperature contact 24 closes at nearly  $40^{\circ}\text{C}$ , and activates the relay 17 <sup>through</sup> ~~over~~ an isolating transformer 13, turning on the blower motor. However, because of the series chokes, the motor receives a phase voltage of only 50 V, so that it will operate at only approximately 725 rpm. At that speed, the blower operates completely noiselessly, but the cooling is already so efficient that it suffices for loads up to 500 a at a room temperature of  $25^{\circ}\text{C}$ . If the load is greater, the temperature of the vessel will increase to above  $40^{\circ}\text{C}$ , and the second temperature contact 25 will close. Then the relay 12 is activated through the isolating transformer 14, the chokes are bypassed, and the motor runs at full rpm. If the temperature drops, this process is reversed. The contacts are in parallel with condensers, which serve to reduce sparking during turning off and thus <sup>17</sup> protect the contacts. The blower motor is protected by a motor ~~protection~~ switch 16.

c) Anode heating:

In order to prevent condensation of mercury ~~mer~~ in the anode spaces during pauses in operation, and when the unit is operating at a low load, the anodes are heated by small hantels of 35 w each. They are heating rings of  $90 \times 20$  dimensions, made by the firm of Elektrowarmer at Doeblin. They are attached at the lower end of the anode insulator (position 28 in circuit diagram 201-92-2711). They are supplied from an isolating transformer 15. The blower relay 17 cuts off the heating as soon as the blower is turned on, because the load current will then heat the anodes sufficiently. The figure quoted above for the power is still very high. The last units, Nos. 101, 102, and 103, had the secondary voltage of the heating transformer reduced from 220 to 180 V, so that its rated power could be lowered.

f) Indication:

Breakdowns are indicated by a signal lamp on the front panel. There are also

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terminals to which an additional signal lamp to be attached to the control panel can be connected, or, instead of this lamp, a drop relay which actuates a ~~alarm~~ <sup>alarm</sup>. This connection operates at a power of 1' w.

The following occurrences are indicated:

- 1) Failure of ignition or of excitation, caused by a ~~rest~~ <sup>de-energized</sup> contact of the exciter ~~alarm~~ relay 5.
- 2) The response of the grid blocking through contact 14 and 15 of the auxiliary relay 56.
- 3) Increase of temperature of the bottom of the vessel to above 60°C through the temperature contact 26.

It is expected that the cathode of the rectifier, and with it, the entire ~~frame~~ <sup>frame</sup> and the parts connected to it, can have a high potential up to 2000 v against ground. For that reason, all parts are separated from the auxiliary network by isolating transformers with a ~~transformer~~ <sup>transformer</sup> voltage of 7 kv. The isolating transformer II supplies the part of the circuit which has a high potential, while the indicator lines run into the circuit through the isolating transformer I2. Transformer II also supplies the relays of the blower circuit. All isolating transformers are equipped with a grounded winding between primary and secondary windings, in order to prevent the high voltage from reaching the low-voltage side in case of a breakdown of the transformer insulation.

#### 6. Data for Starting Operation

##### a) Examination of the vessel:

It is recommended to check the vessel for proper condition before starting operations. For this purpose, the insulation between the anode- and grid connections and the cathode is tested with sinusoidal voltage. The lines must be removed from the anodes. The anodes must maintain a constant voltage of 18 to 20 kv<sub>eff</sub>, although at the beginning occasional breakdown starting at voltages of approximately 15 kv are permissible. For the grids, the values are 7 and 3 kv. Lower values mean a poor vacuum. If the vessel leaks so badly that it is under atmospheric pressure on the inside, the anodes can stand a voltage of about 11 kv, and grids about 5 kv. When the excitation is first turned on, the interior of the vessel is to be watched through the observation window in the ~~xy~~ cover. The color of the discharge should be a clean bluish violet. Dirty white or even reddish color indicates that air is entering the vessel.

**SECRET****b) Setting of excitation:**

The excitation current at the ammeter 4 should be 6 to 8 A, if there is no load on the vessel. The phase position of the three exciter anodes must be set in such a manner that each exciter anode will be ignited when the main anodes next to it should ignite. *This purpose provision is made for reverting to it should ignite. This is accomplished by exchanging the connecting lines.* If the phase displacement of  $120^\circ$  each caused thereby should be too coarse, a phase displacement of  $60^\circ$  can be carried out by moving the primary connections of the stray transformers 1 from the terminals 1 to the terminals 2. Determining the proper position is best carried out by means of an oscilloscope.

**c) Grid blocking**

If the rectifier is loaded with the rated current, the attraction coil of the blocking relay 54 must have a current of 12 mA, or 22 mA in case of a polarized relay. The relay will then block, if there is an over-load of 110%.

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**SECRET**ILLUSTRATIONS

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201-S2-3211: Circuit diagram for rectifier unit 7/6, No. 101 and No. 102, with auxiliary apparatus units Nos. 115 and 116 (WB No. 54004). (Apparatus list AL 102).

Gitterbeaufschlagung: Grid <sup>Supply</sup> Impedance

Gitterspannung: Grid blocking      Gittersteuerung: grid control

Alle Leitungen: all lines

auf Erdfpotential schwarz: Ground potential, black yellow

auf Kathodenpotential gelb: Cathode potential, black (Note: the colors are not visible in the photograph)

am Gefäßes schwarz: vessel, black

Erregung: excitation

Legende der Klemmenleisten ...: position of terminal strips and vessel connections

Stromrichtergefäß: rectifier vessel

Saugstutzen: suction sleeve

Anschluß-Klemmenleiste: Connection terminal strip

Abgabe: output

Windungen: turns

Frontfelddose: front indicator lamp

Druckknopf: pushbutton

201-S2-3212: Rectifier unit 7/6 No. 97, with auxiliary apparatus unit No. 111.

WB No. 54003 (Apparatus list AL 101)

Nach den neuesten Versuchsergebnissen...: according to latest test results:

"resistance"

alle nicht beschrifteten Leitungen: all lines which are not marked

Schauloch: observation window

Rest of legend same as above.

201-S2-4299: Rectifier unit 7/6, Nos. 98-100, with auxiliary apparatus units

Nos. 112-114, WB 54003 (Apparatus list AL 102).

Legend same as above.

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